PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 : A01K 63/04

A1

(11) International Publication Number: WO 00/64246

(43) International Publication Date: 2 November 2000 (02.11.00)

(21) International Application Number: PCT/CA00/00453

(22) International Filing Date: 25 April 2000 (25.04.00)

(30) Priority Data:
60/131,163 26 April 1999 (26.04.99) US

(71)(72) Applicant and Inventor: MACDONALD, Ivan [CA/CA]; P.O. Box 45, L'Ardoise, Nova Scotia B0E 1S0 (CA).

(74) Agents: O'GORMAN, Hugh et al.; Smart & Biggar, 900-55 Metcalfe Street, P.O. Box 2999, Station D, Ottawa, Ontario K1P 5Y6 (CA).

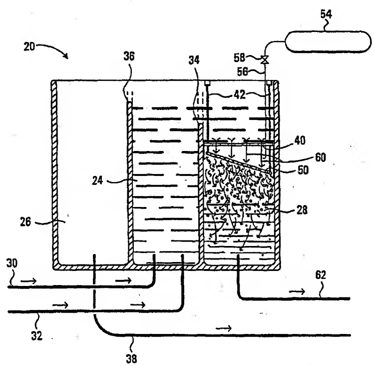
(81) Designated States: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: WATER OXYGENATION AND SYSTEM OF AQUACULTURE

(57) Abstract

Low pressure oxygenation of a flow of water, for example useful in providing oxygenated water in aquaculture systems for raising fish, involves providing an enclosed chamber (28) to which oxygen is supplied at atmospheric pressure and delivering a continuous flow of water into the upper region of the chamber. The water is sprayed onto a diffuser (50) which breaks up the water flow to produce a spray of droplets and foam which mix intimately with the oxygen atmosphere as the water spray drops downwards. Oxygenated water from the lower end of the chamber is delivered to a pond to supply oxygen that is usable by fish being raised in the pond.



FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece			TR	Turkey
BG	Bulgaria	HU	Hungary	ML	Mali	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MN	Mongolia	UA	Ukraine
BR	Brazil	IL	Israel	MR	Mauritania	UG	Uganda
BY	Belarus	IS	Iceland	MW	Malawi	US	United States of America
CA	Canada	IT	Italy	MX	Mexico	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NE	Niger	VN	Viet Nam
CG	Congo	KE	Kenya	NL	Netherlands	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NO	Norway	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	NZ	New Zealand		
CM	Cameroon			PL	Poland		
CN	China	KR	Republic of Korea	PT	Portugal		
CU	Cuba	KZ	Kazakstan	RO	Romania		
CZ	Czech Republic	LC	Saint Lucia	RU	Russian Federation		
DE	Germany	LI	Liechtenstein	SD	Sudan		
DK	Denmark	LK	Sri Lanka	SE	Sweden		
EE	Estonia	LR	Liberia	SG	Singapore		

WATER OXYGENATION AND SYSTEM OF AQUACULTURE

This invention relates to a new or improved method and apparatus for the oxygenation of water and to a system of apparatus and a method for aquaculture, particularly suitable for the rearing of fish in ponds. Although described herein in relation to aquaculture, the oxygenation method and system disclosed has other applications e.g. in waste water treatment arrangements or in clearing contaminants from various aqueous solutions where oxygenation can form a crucial step.

The invention disclosed herein is particularly useful for growing fish in floating fish pens with nets in ponds. The disclosed system produces in an efficient manner a supply of water that is enriched with oxygen, and delivers the oxygenated water directly to the fish in the ponds.

Description of the Prior Art

Fish grown in aquaculture facilities are typically grown in three stages. The first consists of production of the fry (the babies from eggs) and is primarily a breeding and initial rearing phase which must be carried out in fresh water hatcheries. Trout and salmon, whether destined for fresh or salt water, are typically reared to about a 3 to 8 gram size in these breeding facilities before moving to the second stage. The second or fingerling stage, must be carried out in fresh water and involves rearing the fish from fry to fingerlings. This stage is typically performed in raceways, tanks or ponds. The fish weight is typically increased from about 5 grams to approximately 100 grams or whatever size is required. The trout or salmon so raised may then be released to the wild i.e. used to seed streams, rivers, lakes, etc. or, if being raised for food purposes, will then pass to a third stage. This third and final, or grow out stage, typically consists of pens located in the ocean, lakes, rivers, natural or man-made ponds, or sometimes even tank or raceway farms. This stage can either be carried out in fresh water, salt water, or brackish water and involves growing the fingerlings to adult market fish.

This invention is primarily applicable to the second and third stages, i.e. the rearing of fish and other species in land based aquaculture facilities from fingerlings to 'adults'. The current state of the art for the second stage is the use of

raceways or tanks. These types of containment would also be considered current state of the art when used for the third and final growth stage in land based aquaculture facilities. Under this system, a natural flow of fresh water is directed through a series of steel, concrete or fibreglass containment's in which the fish are placed. Typically these containments are arranged in series down a slope or the side of a hill. Fresh water is introduced into the first containment, passes over the fish, is depleted of oxygen, and is then discharged and re-aerated before it is introduced into the second containment. The steps of oxygen depletion, discharge, re-aeration and introduction into another containment may be repeated in varying numbers of cycles. Reusability of the water in such systems has many limiting factors, including for example, accumulation of solids, PH and ammonia, but most importantly, depletion of oxygen, and hence the ability to cost effectively replace oxygen, is the biggest constraint.

It is well known in the art that fish growth in such systems is primarily constrained by the availability of oxygen in the water which allows the fish to convert the provided food into flesh. The efficiency of the containment design, the water exchange (i.e. available oxygen) and one's ability to cost efficiently re-aerate the water between each use while also controlling the other limiting factors, controls the cost of production and hence commercial viability. On a steeply sloping site where there is a large drop between the discharge of one containment and the inlet of the next containment, a 'gravity-powered' waterfall can provide adequate re-oxygenation. This is not the case where the 'drop' between the containment is less than 5 feet. The current art provides means for artificial oxygenation of water between containments by diverting some water, typically 5% - 10% of the total flow, into various types of pumped oxygenation mechanisms. However oxygenation mechanisms require constant power. They must also very reliable because if the oxygen content of the water drops below about 60% even for a couple of minutes fish will start to die. Consequently with existing systems constant monitoring, high reliability and backup systems are required, all of which add to the capital and operating costs of rearing fish, as well as greatly increasing the risk of catastrophic loss.

Another limitation of traditional raceway and tank containments is that the water has the highest oxygen content where it enters each containment, hence the

fish tend to crowd into this area. This limits the holding capacity of a given containment thereby reducing the number of fish that can be raised at one time. This results in a higher capital cost per pound of fish raised. Yet another limitation to raceway and tank containments is that the waste products from the fish in the upper containment is retained within the water stream and therefore carried to fish in lower containments. This provides for accumulation of waste, thereby lowering the quality of the water as it flows from containment to containment, and hence limits the total number or capacity of containments supportable from a given natural water source. Typically the water can be used a maximum of five times.

Still yet another limitation of the current art is the capacity of the minimum flow. In higher latitudes there is usually an adequate supply of fresh, natural water during fall through to spring. However, the amount of brook or stream water available at summer minimum levels dictates the maximum annual capacity of the site and determines the number of fish that can be raised at the facility. The ability to take maximum advantage of the available minimum flow over the summer period dictates the maximum number of fish that can be grown, hence the yearly production capacity for a given capital expenditure. Simply put, one can cost effectively grow whatever fish one can nurture through the worst period in the year. However, by adding oxygen to increase the fish-holding capacity during this low flow period, annual production can be greatly increased in a cost effective manner.

Fish are also raised at fresh water aquaculture facilities from the fingerling stage to the adult stage in flow-through ponds, rivers and lakes. These have the advantages of providing more space for the fish to spread throughout a larger area. However the oxygen content of the water throughout the larger containment area needs to be above a minimum in order for fish to be able to use the increased space. This can be provided by pumping a portion of the water from the pond, through an oxygenation column of some sort, or by pumping the water through an aeration fountain or by using some other type of mechanical aeration device. Any of these mechanisms again requires a reliable power source, and must itself be reliable, as any failure can relatively quickly result in the oxygen content of the water falling below that required to keep the fish alive.

The limitations of the current aquaculture art result in high capital investment required to build containments which in turn raises the average cost per pound to rear standard market-ready fish. The cost of required electrical power for pumps and the continuous human monitoring leads to high production costs. The high amortized capital cost per pound of fish and the high production cost per pound of fish limit the feasibility of aquaculture sites that have low natural water flow. Additionally the current art requires reliable power sources and oxygenation or aeration equipment. Further limitations of the current art restrict the re-usability of the available water source, (GPM x Number of reuses = increased site capability and profit).

Summary of the Invention

The present invention provides a method for low-pressure oxygenation of a flow of water comprising: providing an enclosed chamber and delivering a flow of oxygen to said chamber to create therein an atmosphere that is at least predominantly composed of oxygen; delivering a continuous flow of water into an upper region of said chamber and dispersing and creating turbulence in the water delivered to the chamber such that the water mixes intimately with the chamber atmosphere and absorbs oxygen therefrom; permitting the dispersed turbulent water to fall under gravity to a lower region of said chamber further absorbing oxygen from bubbles entrained therein while it falls; and withdrawing a continuous flow of oxygenated water from the lower region of the chamber.

As used herein the term "low-pressure" means pressure of the same order as atmospheric pressure. The oxygen supply may be delivered from a high pressure tank, but is throttled through a valve before being released into the enclosed chamber, the latter operating generally at a pressure close to atmospheric pressure. While it is appreciated that the oxygen absorbing capacity of water increases with increasing pressure, the present method and system provide adequate oxygenation of the water at atmospheric pressure and thus avoid the need to employ pumps and a power source for the pumps. The oxygenation method described herein operates at a pressure that is just greater than atmospheric, i.e. a pressure equivalent to that produced by a head of water of between about 15 and 60 cm, as opposed to pressures of from 2 to 40 atmospheres used in some other oxygenation devices.

The oxygenation method can be performed in an aquaculture system without the need for bubble aerators or the like. As disclosed herein, the flow of water is delivered to the chamber through a roof having adjustable apertures, to impinge upon and to be broken up into innumerable droplets and be foamed by a diffuser suspended below the roof, and to mix intimately with the oxygen atmosphere in the chamber as the water droplets fall to the bottom of the chamber. Oxygen from the high pressure tank is piped into the chamber in a controlled manner through the valve to provide sufficient oxygen to achieve the desired degree of oxygenation in the water. Oxygenation levels in excess of 100% of the oxygen carrying capacity of the water at normal atmospheric pressures are easily possible, but are not always desirable in aquaculture applications since oxygen above the 100% level is likely to be lost through bubbling out of the water in the ponds.

From another aspect the invention provides a system for oxygenating a flow of water comprising: a chamber; vertically extending walls, a base and a roof defining the limits of said chamber; means for delivering a flow of oxygen to said chamber to create therein an atmosphere that is predominantly composed of oxygen; means for delivering a continuous flow of water into an upper region of said chamber and means for dispersing and creating turbulence in said flow of water within the chamber atmosphere, the turbulent water falling under the effect of gravity through said atmosphere to be oxygenated thereby, and gathering in a lower region of said chamber; and means for continuously withdrawing oxygenated water from the lower end of said chamber.

Turbulence, break up, droplet and spray formation in the water is created by a diffuser that is positioned in the upper region of the chamber to be impinged by the incoming flow of water. Preferably the flow of water is delivered through the roof of the chamber, the roof including a number of apertures which are adjustable in size and through which the flow of water is directed onto the diffuser which is preferably suspended below the roof.

The apertures are sized in relation to the rate of water flow to maintain a water seal above the chamber to prevent the escape of oxygen therefrom, the flow of oxygen to the chamber being adjusted to ensure that no excess pressure develops in the chamber.

The system can readily be disposed so that the flow of water therethrough is effected solely under the force of gravity.

A practical aquaculture farm employing the principles of the present invention would entail providing a series of ponds (or groups of ponds) arranged at successively lower intervals, e.g. down a hillside, water being fed through an oxygenation chamber in accordance with the invention upstream of each pond or group of ponds, and the water being passed successively through the ponds or group of ponds. The water can be drawn from a natural watercourse such as a river or stream to which it is returned after passing through the last pond or group of ponds. The aquaculture arrangement as described above can operate without any external source of power other than gravity, when an adequate flow of water is available from the watercourse. In times of extremely low flow in the watercourse, a portion of the water can be recirculated from the outlet of the downstream pond by means of a pump to the oxygenation chamber upstream of the upstream pond.

Preferred embodiments of aquaculture systems employing the principles of the present invention overcome the current limitations of known systems and provide the following advantages:

(a) Since there is no power supply required, there is no need for continuous onsite monitoring of power devices, failure of which would cause rapid fish death.

(b) Wastage of oxygen that is associated with bubbling systems which allow a portion of the oxygen to escape into the air, or produce bubbles that are too big for the fish to use is avoided. Transfer efficiency of oxygen from the oxygen tank to the fish as high as 90 to 95% can be achieved.

(c) The system can automatically adjust (within limits) for variable water flow rates.

(d) By achieving increased oxygen content in a large inflow of water, evenly delivered to the ponds, "hot spots" of oxygenated water are avoided and the fish are therefore evenly distributed throughout the containment area of the pond, which greatly increases the site capacity.

In current aquaculture systems the maximum capacity of the facility is reduced and/or the quality of the fish produced is lowered due to fish crowding tendencies at or over the incoming oxygen containing water flow. Existing systems also require expensive complex valving systems to drain individual ponds while the system remains in operation. In existing systems the collection and cumulative build up of waste products deteriorate the water quality and thus diminish its reusability.

Systems built embodying the teachings of the present invention can achieve greatly reduced capital costs per pound of fish produced and require little maintenance. Thus low cost production can be achieved using a form of containment that is natural and unobtrusive. All that is required is a site that has sufficient slope to create a drop between successive ponds (or groups of ponds) of the order of 1 to 2 meters which is sufficient to achieve adequate oxygenation of the water. This is of particular value since sites previously regarded as marginal due to limitations of the prior art methods now become usable. Likewise remote areas which lack a reliable external power source (as required by prior art systems) can be utilized.

Although described herein chiefly in the context of aquaculture for raising fish, it will be evident that the principles discussed above and disclosed elsewhere herein are useful in oxygenating water in other situations, e.g. in the cleansing of waste water, the purification of water from containments etc.

The invention will further be described, by way of example only, with reference to the accompanying drawings wherein:

Figure 1 is a schematic plan view of an aquaculture layout containing a series of three ponds each containing multiple fish pens;

Figure 2 is a somewhat schematic sectional view showing an oxygenation system interposed between successive ones of the ponds;

Figure 3 is an enlarged view of the oxygenation system of Figure 2;

Figure 4 is a partial isometric view of an upper portion of the system of Figure 3;

Figure 5 is an enlarged view of a portion of Figure 3; and

Figure 6 is a partial vertical sectional view illustrating water flow in a fish pond.

As seen in Figure 1 the aquaculture system comprises a series of ponds 2, 4, 6 each containing a plurality of individual pens 2a, 4a, 6a respectively. The ponds 2, 4, 6 (which may either be inground or aboveground) are arranged at intervals down a hill, the pond 6 being at a level 1 to 2 meters below the pond 4 which in turn is at a level 1 to 2 meters below the pond 2. The ponds are positioned in proximity to a natural watercourse such as a river or stream 8 to draw water from an upstream location 10 through a supply conduit 12 and return water to the river or stream at a downstream location 14 through an outflow pipe 16, the downflow location being at a level at or below the water level in the pond 6.

The supply conduit 12 delivers water from the stream under gravity to a first control box 18 wherein a wall or weir (not shown) is used to establish a system for controlling the incoming water flow rate to a desired level. Similar control boxes 20 and 22 are arranged upstream of the ponds 4 and 6, and each control box incorporates a system for adding oxygen to the incoming water and delivering oxygenated water to the associated pond 2, 4, 6. Each of the control boxes operates on the same principle which will now be described in relation to control box 20 which is arranged between the ponds 2 and 4 and shown in Figures 2 and 3. The control box 20 provides a containment within which are defined a inlet chamber 24, an overflow chamber 26 and an oxygenation chamber 28. Water is supplied to the inlet chamber 24 through a first conduit 30 leading from the pond 2 and a second conduit 32 leading from the overflow chamber (not shown) of the control box 18. The control box 18 differs from the control boxes 20 and 22 in that its normal supply of water is delivered solely through the conduit 12 leading from the watercourse 8.

Water supplied to the inlet chamber 24 rises therein until it passes over a weir formed by the top of a dividing wall 34, and after spilling over this dividing wall 34 can flow into the oxygenation chamber 28 as will hereinafter be described. A second dividing wall 36 forms with its upper edge a weir so that excess water supplied to the inlet chamber 24 will pass over the weir 36 and fall into the outflow chamber 26 to be delivered therefrom through an outlet pipe 38. It will be noted that the weir 36 acts to maintain above the chamber 28 a predetermined depth (preferably about 15 to 30 cm)

of water above the chamber 28. The height of weirs 34 and 36 are adjustable by manually adding additional horizontal pieces of wood ('stop logs', not shown) or similar, held by vertical slots or grooves in the chamber walls.

As best seen in Figures 4 and 5, the upper end of the chamber 28 is closed by a roof 40 suspended on chains 42 which are adjustable in height, and occupies substantially the entire cross section of the chamber 28. Each chain 40 is supported in a respective slotted holder 43 mounted at the upper end of the control box 20, the length of chain suspended below the holder 43 being adjustable link-by-link when it is desired to change the height of the roof 40 or to level it. The roof is formed with a series of smaller apertures 44 and one larger elongate aperture 46 extending therethrough from top to bottom. The aperture 46 includes an adjustable closure member 48 by means of which the open cross section of the aperture 46 can be adjusted in area (by threaded rods or the like, not shown) or closed off as desired.

A diffuser 50 is suspended by chains 52 from the lower surface of the roof 40. The diffuser 50 is a rectangular figure formed by overlapping layers of wire or the like providing a very porous structure having a host of closely spaced elements (not shown, such as multiple offset layers of wire mesh) which will act to break up and disperse the falling water. The diffuser 50 is supported at an angle as shown so that debris entering the chamber 28 with the water will be swept off.

A supply of oxygen from a tank 54 is delivered to the chamber 28 through a conduit 56 at atmospheric pressure under the control of a manually adjusted valve 58 to create within the chamber 28 an atmosphere that is composed entirely or at least largely of oxygen.

From the foregoing description it will be appreciated that in operation water supplied to the inlet tank 24 when the latter has been filled will spill over the wall 34 and accumulate above the roof 40 to be delivered into the oxygenation chamber 28 through the apertures 44, 46 in the roof. The falling flow of water as represented by the arrows 60 in Figures 3 and 5 will impinge upon the diffuser 50 and will be fragmented and churned thereby, breaking up the water flow into a spray of droplets and foam as it passes through the diffuser plate and falls towards the bottom of the chamber 28. This finely divided spray while falling mixes intimately with the oxygen

atmosphere in the chamber and absorb oxygen to a great extent, entraining bubbles of oxygen as it falls to the bottom of the chamber and accumulates there with an upper surface at approximately the water level in the lower pond. The spray of water falling to the bottom of the chamber 28 include bubbles of oxygen, and the turbulence created by the falling spray in the water at the bottom of the chamber 28 has the effect of breaking up the entrained oxygen bubbles into finer bubbles which are more easily absorbed by the water by virtue of their larger total surface area. From the bottom of the chamber 28 the oxygenated water flows under gravity continuously from the lower end of the chamber 28 through a submerged conduit 62 from whence it is delivered to the pens 4a of the pond 4. This turbulence helps to break up entrained oxygen bubbles in the spray and creates finer bubbles which are more easily absorbed into the water because of the enlarged interface between these finer bubbles and the water. Small bubbles of oxygen present in the water accumulating at the lower end of the chamber 28 will be entrained with the water entering conduit 62 and will become totally absorbed by the water before it reaches the pond 4. Between the height of the water level accumulated in the lower end of the chamber 28, and the lowest point reached by the conduit 62 delivering the oxygenated water to the pond 4, there may be a drop of from 3 to 5 meters producing an increased pressure which together with the turbulence which persists in the water flowing in the conduit 62 and the time taken by the water to transit the lower chamber and conduit to the bottom of the pond 4 greatly enhances the absorption of oxygen into the water, and thus enhances the transfer efficiency of oxygen to fish in the pond.

With the arrangement disclosed, the rate of oxygenation can easily reach and exceed 100% of the oxygen carrying capacity of the water at atmospheric pressure.

The flow rate of water through the roof 40 into the chamber 28 is adjusted to a desired level by adjustment of the height of walls 34, 36, and of the roof apertures 46, 44, and a corresponding flow of oxygen is also delivered to the chamber 28 by suitable adjustment of the control valve 58. Once these parameters have been selected, the control box can continue to operate unattended and without adjustment, reliably maintaining the desired conditions of oxygenation. The flow rate of water selected will initially be less than the rate of delivery of water into the inlet chamber 24

such that water accumulates above the roof 40. This continues until the depth of water above the roof (normally from about 15 to 60 cm) is sufficient to increase the flow rate through the apertures 44, 46 to exactly match the delivery range of water into the inlet chamber 24. Should the inlet chamber flow rate increase, the depth of water above the roof increases which causes an increase in the flow of water through the apertures 44, 46. The device is therefore, within reasonable limits, self-adjusting to variations in water flow rates. The adjustment of the aperture 46 is designed to ensure that for a given flow rate of water into the inlet chamber 24, there will always be sufficient water above the roof to maintain the water seal. In the event that a large excess of water is delivered to the inlet chamber 24, excess water will spill over into the overflow chamber 26 once the water level reaches the top of the wall 36. The level of the latter determines the maximum head of water which can exist above the roof 40.

The oxygenation device described above in relation to Figure 3 can be used where there is a height difference of at least about one meter between the water level of the incoming flow to the chamber 24 (i.e. the level in a preceding pond, or in the case of the control box 18 the level in the supply conduit or watercourse location 10) and the water level in the lower pond.

The constant flow of water through the apertures 44, 46 in the roof 40 inhibits any upwards flow of oxygen through the slots and minimizes oxygen loss. The rate of water flow downwardly through the apertures 44, 46 is in excess of the natural rise rate of oxygen bubbles in static water, and this prevents escape of oxygen through the apertures 44, 46. The water seal is maintained by a predetermined depth (from 15 to 60 cm) of water maintained above the roof 40 by the wall 34. A minor amount of water will also flow downwards through the clearance between the periphery of the roof 40 and the walls of the chamber 28, so that there will be minimal or no escape of oxygen at this region. Accordingly, it becomes possible to ensure that 95% or more of the oxygen delivered through the conduit 56 is absorbed by the water flowing through the chamber 28.

The aperture 46 is adjusted as required, which is infrequently, e.g. every few days, or after a heavy rainfall, etc. commensurate with the flow of water available from the feeding watercourse 8 which will of course vary depending upon the time of

year. If the total flow cross section of the apertures 44 and 46 is too large, then too much water will flow into the chamber causing loss of the water seal above the roof and allowing oxygen to escape. If the adjusted area of the apertures 44, 46 is too small, then too little water will flow through the oxygen chamber (excess water being bypassed through the overflow chamber 26 and the outlet pipe 38 and delivered to the control box of a pond following the one being bypassed, or to the brook outlet 16, without being oxygenated) so that less than the maximum possible oxygenated water is delivered to the fish.

By means of the valve 58 and other simple regulators and the like (not shown) the oxygen flow can be adjusted to match the water flow rate through the chamber 28 and the desired degree of oxygenation. In practice adjustments are required only infrequently, e.g. only as the seasonal water flow rate or seasonal temperature (hence degree of oxygenation desired) change or in response to major changes in water flow which result from higher rainfalls. Once set, the system is effectively self regulating. The oxygen levels in the fish pens can be monitored automatically or manually and can be adjusted as required simply by varying the rates of flow of water and oxygen into the chamber 28.

From the conduit 62 the oxygenated water is delivered into the individual pens 4a of the pond 4 as indicated in Figures 1 and 6 of the drawings. As shown, the conduit 62 has an outlet 64 delivering oxygenated water centrally into each of the pens 4a. The individual pens 4a within the pond 4 are defined by nets 66 suspended from perimeter walls 68 and floating crosswalks 70 of the pond. The fish pen nets 66 are laid right to the bottom of the pond. Because the oxygenated water is delivered centrally into the pen in substantially bubble-free condition, there is no tendency for the fish to congregate at the outlet pipe 64, but rather they are more likely to be uniformly spaced throughout the pen 4a, the more so since the water is substantially completely oxygenated. This has a number of benefits. It will be evident that the quantity of fish contained in a pen 4a can be increased when the fish are more uniformly distributed. The water circulation and flow, plus the small current created by the fish themselves which tend to swim in a circular pattern in the well oxygenated water, causes the settling of waste products from the fish in the still or stationary water just outside the limits of the nets 66 as indicated at 72 and 74 in Figure 6. This settling

action removes the contaminants from the water that the fish occupy, and furthermore means that the water flowing to the pond outlet (not shown) and into the next downstream pond is of higher quality than could be achieved by prior art systems. This in turn facilitates re-oxygenation of the water, and allows more ponds to be built in series from the available natural water flow, thus increasing production capacity. Periodically (i.e. between production batches) each pond is drained and the waste products removed. The settling of these wastes products at the locations indicated at 72 and 74 facilitates their removal.

With the system described in relation to Figures 1 through 6 it will be noted that in the event it becomes necessary to isolate one of the ponds for cleaning or servicing, this can readily be accomplished by directing all of the incoming water reaching the associated control box 18, 20, or 22 to pass through the overflow chamber and into the pipe 38 from which it can be diverted downstream without passing through the associated pond that is to be taken out of service.

To bypass for example the pond 4 it is simply necessary to plug the outflow conduit 62 so that all of the water delivered to the inlet chamber 24 will pass through the overflow chamber 26. Of course at the same time the oxygen flow to the chamber 28 is cut off to avoid waste. Alternatively the relative height of the weirs formed by the walls 34 and 36 could be changed. These walls are adjustable in height via the addition or removal of 'stop-logs' or the like (not shown), and when the weir 34 is positioned above the weir 36, no water will flow to the oxygenation chamber 28, but rather it will all flow to the overflow chamber 26. To prevent back flow into the pond that is to be isolated, it is also necessary to plug the outlet pipe (not shown) from that pond. The isolated pond can then be drained and cleaned or serviced as desired. In fact to achieve the above isolation step no expensive valves are required but rather the desired effect can be achieved by utilizing simple pipe plugs, stop logs or the like (not shown). This improves reliability of operation and lowers the capital cost structure since flow control valves of the size required (for example in excess of 50 cm for the pipe sizes involved can be dispensed with, such valves are of course expensive, and could be problematic when exposed to freezing winter conditions.

Even the outflow of water from the downstream pond 6 is reasonably clean so that in times of low flow conditions in the watercourse 8, it is possible to

recirculate water from the outflow pipe 16 by means of a pump 76 which returns the water through a pipe 74 to the control box 18.

A comparative test was conducted raising a first batch of fish in an aquaculture site generally as shown in Figure 1 in embodying the oxygenation system described in relation to Figures 1 to 6, and raising a second batch of fish in accordance with the best prior art practice known to the inventor. Fish supplied from the same fish breeder were used in both batches and raised over a 20 week period. It was found that the fish raised using the teachings of the present invention had a higher survival rate and more than twice the weight gain of those raised in accordance with the prior art practice.

Experience has shown that practice of the present invention allows the rearing of a greater number of fish in an available minimum flow of fresh water than can be achieved through current practice. This is due to (a) the avoidance of crowding in the growing facility due to the widespread availability of oxygenated water, and (b) the avoidance of water quality problems caused by accumulation of fish wastes in the water.

Thus the invention as described herein, by making it possible to rear a greater number of fish to a greater weight than was possible using prior art systems, reduces the capital cost and production cost per pound of fish raised. It also allows maximum use of the available minimum natural water flow during a relatively dry summer. The system in accordance with the invention provides a gravity powered means of oxygenation of the water, thus cutting costs by eliminating the need for an electrical or other power source, and more importantly providing high reliability of the oxygenation process thus reducing costs which otherwise would be necessary to provide backup systems, on site personnel, high reliability monitoring devices etc.

The control box as described above in relation to Figures 3 to 5 allows the oxygen content of water used in land based aquaculture systems to be greatly increased thus producing corresponding increases in food conversion rates, growth rates, and weight gain of the fish. The combination of the water seal above the roof 40 and the gravity pressurized pipe flow through the conduit 62 to the bottom of the associated pond makes it possible to produce water that is over supersaturated with

oxygen (e.g. that includes in excess of 200% of the oxygen absorbing capacity of water at atmospheric pressure) without any power or other mechanical devices that are prone to failure. The system provides a broad mass of oxygen enhanced water rather than narrow columns or areas provided by prior art devices such as air blowers, air stones, oxygen columns, service aerators, etc. This in turn allows a greater fish population to be bred in the available water volume and containment space.

In practice it has been found beneficial to adjust the level of oxygenation in the water so that it is about 140% at the bottom of the pond as supplied from the outlet 64. From the outlet 64 the water diffuses into the pond and presumably rises during which time it is consumed by the fish. Measurements of oxygenation in the water about 30 cm below the pond surface indicate an oxygen content of about 100%, and this is believed to be ideal for making maximum oxygen available to the fish whilst avoiding wastage which would occur by oxygen bubbling out of the water and releasing to the atmosphere.

A significant advantage of the present invention is that it provides a relatively large volume of well oxygenated water (i.e. the entire incoming water stream) rather than a smaller stream of highly oxygenated-water as in the prior art. The large volume oxygenated stream provided by the present invention is more easily diffused throughout the pond and thus avoids fish crowding.

It will be appreciated that the embodiments of the invention illustrated in the drawings and discussed above are given by way of example only and are not limitative. Those skilled in the art will recognize that variations of the particular layouts and mechanisms disclosed are possible. For example a two chamber oxygenation device could be used, with the excess water flow being handled by mechanisms known in the prior art. Additionally, a two part chamber device could be used (not shown) instead of the three-part chamber illustrated in Figure 3, with excess water overflow being handled through an outlet pipe rather than through an overflow chamber as shown.

In some situations it might be desirable to integrate the control boxes 16, 20 and 22 into one end of one of the adjacent ponds 2, 4 and 6. For example the chambers 26 and 28 could be built into an outlet wall of an upstream pond, the upper

pond constituting in effect the chamber 24, and the adjustable wall 34 being an outflowing pond weir, the chambers 26 and 28 being built into the wall of the pond. Similarly it would be possible to reconfigure the oxygenation device described in relation to Figure 3 to incorporate it into an upstream wall of one of the ponds.

The cover or roof 40 of the oxygen chamber could also be varied widely. For example the apertures 44, 46 as shown could be replaced by multiple small holes, louvers, or other adjustable opening providing the desired degree of water flow control while ensuring that a sealing layer of water is retained above the chamber 28.

The cover and screen method of providing a water seal in the oxygenation chamber 28 could also be used in a pressurized system to efficiently produce supersaturated water, i.e. water whose oxygen content is greater than 100%, for use other than in aquaculture, e.g. in industrial situations, waste water treatment and other aerobic chemical engineering processes. The systems and methods disclosed herein are capable of injecting hundreds of litres of oxygen per minute into a flow of 6,000 litres per minute of water flow, which is far in excess of that normally needed for aquaculture purposes, commensurate with what is required for some industrial processes.

CLAIMS:

1. A method for low-pressure oxygenation of a flow of water comprising:

providing an enclosed chamber and delivering a flow of oxygen to said chamber to create therein an atmosphere that is at least predominantly composed of oxygen;

delivering a continuous flow of water into an upper region of said chamber and breaking up and dispersing the water delivered to the chamber to produce a spray of droplets and foam such that the water mixes intimately with the chamber atmosphere and absorbs oxygen therefrom;

permitting the dispersed water spray to fall under gravity to a lower region of said chamber further absorbing oxygen from bubbles entrained therein while it falls; and

withdrawing a continuous flow of oxygenated water from the lower region of the chamber.

2. A method as claimed in claim 1 comprising: providing said chamber with an apertured roof through which said flow of water is delivered under gravity to fall into the chamber;

providing a diffuser structure in said chamber positioned to be impinged by the falling flow of water thus creating the spray of droplets and foam to effect mixing between the water and the chamber atmosphere.

3. A method as claimed in claim 1 or claim 2 comprising the step of periodically adjusting the flow of oxygen in relation to the flow of water to obtain a desired degree of oxygenation in the water withdrawn from the lower region of the chamber.

4. A method as claimed in any one of claims 1 to 3 for low-pressure oxygenation of a flow of water that is supplied to a pond, wherein the oxygenated water is withdrawn through a pipe at the bottom of said chamber and is delivered through said pipe to said pond in substantially bubble-free condition.

5. A method as claimed in claim 4 wherein the level of water in the lower region of the chamber is slightly above the surface water level in said pond so that water flows through said pipe under the force of gravity.

6. A method as claimed in claim 2 wherein the apertured roof is configured such that the flow of water passing therethrough is sufficient to maintain a water seal above said apertured roof to isolate the chamber from external atmosphere.

7. A method as claimed in claim 6 including the step of maintaining a depth of water above said apertured roof to provide a water seal, and adjusting the flow of water such that the downwards velocity of water flow through said apertured roof exceeds the natural rise rate of oxygen bubbles in static water, thus inhibiting escape of oxygen from said chamber.

8. A method as claimed in claim 7 including providing an overflow weir to prevent said depth of water exceeding a predetermined amount.

9. A method as claimed in any one of claims 1 to 8 wherein the rate of withdrawal of oxygenated water from the lower region of the chamber is such that bubbles of oxygen entrained in the falling water spray in said chamber are carried in the withdrawn flow of oxygenated water to be absorbed therein.

10. A method of providing a supply of oxygenated water to an aquaculture pond wherein a flow of water is oxygenated by the method as claimed in any one of claims 1 to 9 and supplied as a substantially bubble-free flow to said pond.

11. An aquaculture method comprising providing a series of ponds arranged in succession; providing a flow of water to a first pond in said series; withdrawing an equal flow of water from said first pond and delivering it to a second pond in said series; and oxygenating the flow of water supplied to each pond by the method claimed in claim 10.

12. The aquaculture method as claimed in claim 11 wherein said ponds are arranged at successively lower levels and wherein water flow to and from each pond is effected under the force of gravity.

13. A method as claimed in any one of claims 10 to 12 wherein the oxygenated flow of water is supplied to the or each pond in substantially bubble-free condition in a central region thereof.

14. A method as claimed in claims 11 or 12 wherein the water used is drawn from a natural watercourse and is returned to the watercourse after the last pond in the series.

15. A method as claimed in claim 14 including the step of recirculating water from the outlet of the last pond to the water supplied to the oxygenation chamber for the first pond, in the event that the available flow of water from the natural water-course is insufficient to maintain a desired water flow rate.

16. A system for oxygenating a flow of water comprising:

a chamber;

vertically extending walls, a base and a roof defining the limits of said chamber;

means for delivering a flow of oxygen to said chamber to create therein an atmosphere that is predominantly composed of oxygen;

means for delivering a continuous flow of water into an upper region of said chamber and means for dispersing said flow of water to produce a spray of droplets and foam within the chamber atmosphere, the water spray falling under the effect of gravity through said atmosphere to be oxygenated thereby, and gathering in a lower region of said chamber; and

means for continuously withdrawing oxygenated water from the lower end of said chamber.

17. A system as claimed in claim 16 wherein said means for dispersing comprises a diffuser positioned in an upper region of said chamber to be impinged by the incoming flow of water.

18. A system as claimed in claim 16 or claim 17 wherein the roof of said chamber includes apertures through which said flow of water is delivered.

19. A system as claimed in claim 18 wherein said apertures are adjustable in area to adjust the quantity of said flow of water.

20. A system as claimed in claim 19 wherein said chamber has a roof that is defined by a horizontal panel having an outline that closely follows that of said chamber, said horizontal panel having a plurality of apertures extending therethrough, at least one of said apertures being adjustable in area, said panel being suspended to lie horizontally between said chamber walls, and being adjustable in a vertical direction.

21. A system as claimed in any one of claims 18 to 20 wherein said apertures are sized in relation to the rate of water flow to maintain a water seal above said roof to prevent the escape of oxygen from the chamber.

22. A system as claimed in claim 21 wherein a weir is associated with the upper end of said chamber and is positioned at a height to establish a maximum depth of water above the chamber roof and thus maintain the chamber at a low pressure not exceeding that produced by said maximum depth of water.

23. A system as claimed in any one of claims 18 to 22 wherein said apertures are sized in relation to the quantity of said water flow such that the downwards flow velocity of water through said apertures exceeds the natural rise rate of oxygen bubbles in static water.

24. A system as claimed in any one of claims 16 to 23 in combination with a water pond connected to the lower end of the oxygenation chamber by means of a pipe through which oxygenated water is delivered to the pond.

25. An aquaculture installation comprising a system as claimed in claim 24.

26. An aquaculture system as claimed in claim 25 including a plurality of ponds arranged in series, each pond being preceded by an oxygenating system as aforesaid, water withdrawn from a first pond in said series being delivered successively through subsequent ponds.

27. An aquaculture system as claimed in claim 26 wherein successive ponds are positioned at successively lower horizontal positions such that a continuous flow of

water can be passed under the force of gravity from the oxygenation chamber preceding the first pond to the outlet of the last pond in said series.

28. An aquaculture system as claimed in claim 26 or claim 27 which is connected to receive a flow of water from a natural watercourse, and to return a flow of water to the natural watercourse after having passed through all of said ponds.

29. A system as claimed in any one of claims 26 to 28 including a recirculation pump by means of which water exiting the last pond can be recirculated to flow into the oxygenation chamber associated with the first pond in the event that an insufficient flow of water is available from the watercourse.

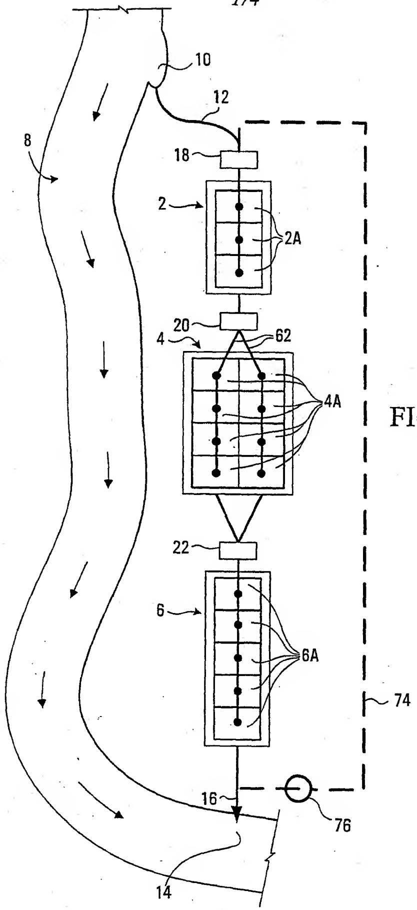


FIG. 1

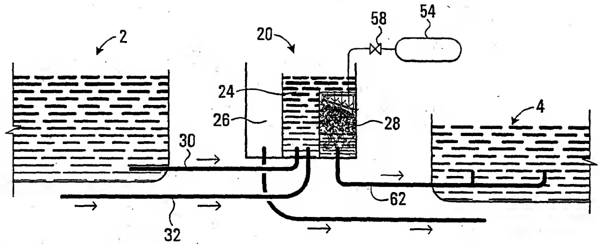

2
20
58
54
24
26
28
4
30
62
32

FIG. 2

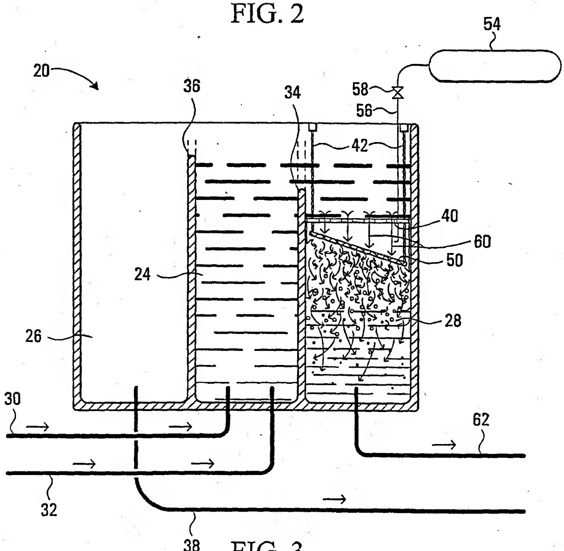

54
20
36
34
58
56
42
40
60
50
24
28
26
30
62
32
38

FIG. 3

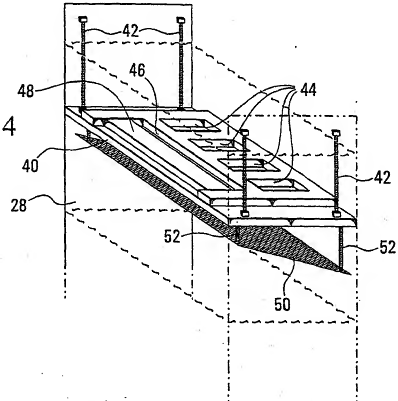


FIG. 4

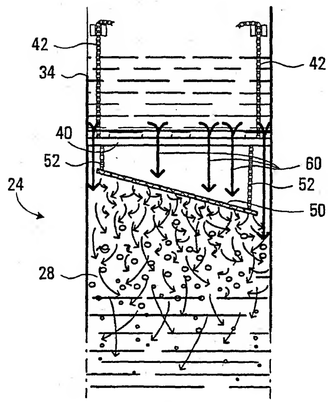


FIG. 5

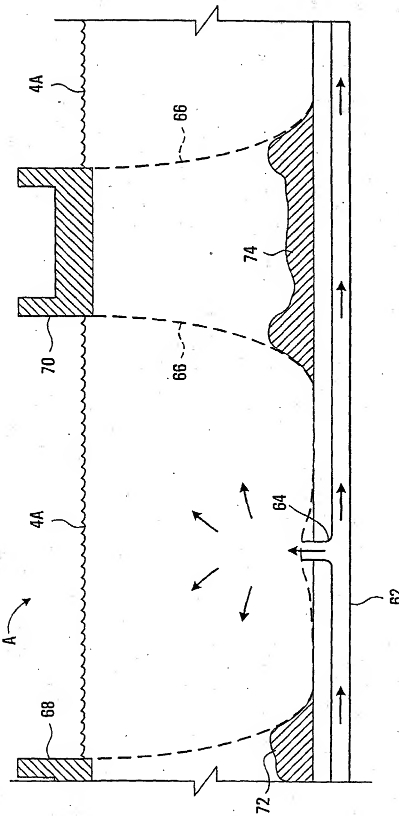


FIG. 6

INTERNATIONAL SEARCH REPORT

International Application No
PCT/CA 00/00453

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 A01K63/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 A01K C02F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 26 38 489 A (LINDE AG) 2 March 1978 (1978-03-02)	1,9, 16-18
Y		4,5
A	page 6, paragraph 3 -page 8, paragraph 1; figure 3	2-6,10, 11,24, 25,29
Y	FR 2 440 338 A (VERNET JACQUES) 30 May 1980 (1980-05-30)	4,5
A	page 3, line 36 - line 41 page 4, paragraph 2; figure 1	1,23
A	EP 0 645 080 A (BATTIGELLI GIUSEPPE ;BATTIGELLI LUCILLA (IT)) 29 March 1995 (1995-03-29) column 3, line 8 - line 47; figures 2,3	1-4, 6-13,16, 17,20, 22,26,27

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
25 August 2000	31/08/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Hinrichs, W

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/CA 00/00453

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 2638489 A	02-03-1978	AT 374079 B	12-03-1984
		AT 598277 A	15-08-1983
		AU 510431 B	26-06-1980
		AU 2814677 A	01-03-1979
		BE 858077 A	24-02-1978
		BR 7705640 A	02-05-1978
		CH 622671 A	30-04-1981
		DD 131335 A	21-06-1978
		DK 377477 A	27-02-1978
		ES 461500 A	01-10-1978
		FR 2362583 A	24-03-1978
		GB 1552278 A	12-09-1979
		GR 63622 A	27-11-1979
		IN 148117 A	25-10-1980
		IT 1084506 B	25-05-1985
		JP 53027598 A	14-03-1978
		NL 7709395 A	28-02-1978
		US 4182268 A	08-01-1980
		YU 203077 A	31-08-1982
		ZA 7705136 A	26-07-1978
FR 2440338 A	30-05-1980	NONE	
EP 0645080 A	29-03-1995	IT 1262202 B	19-06-1996